OPTICAL HEAD UNIT AND
OPTICAL INFORMATION WRITING/READING DEVICE

BACKGROUND OF THE INVENTION

1. Field of the invention

[01]   The present invention relates to an optical head unit and optical information writing/reading device, and more particularly, to an optical head unit and an optical information writing/reading device having a plurality of objective lenses.

2. Description of the Related Art

[02]   A recording density of an optical information writing/reading device is inversely proportional to a square of the diameter of a focal spot formed on an optical recording medium by an optical head unit. In other words, the smaller the diameter of the focal spot, the higher the recording density. The diameter of the focal spot is proportional to a wavelength of a light source and is inversely proportional to a numerical aperture of an objective lens. In other words, the shorter the wavelength of the light source and the higher the numerical aperture of the objective lens, the smaller the diameter of the focal spot. On the other hand, when an optical recording medium (optical disc) is tilted to an objective lens, the shape of a focal spot is fluctuated due to coma aberration, resulting in deterioration of the writing/reading characteristic. The coma aberration is inversely proportional to the wavelength of a light source and is proportional to the cube of the numerical aperture of the objective lens and the thickness of a protective layer of an optical recording medium. When the thicknesses of protective layers of optical recording media are the same, the shorter the wavelength of the light source and the higher the numerical aperture

1

of the objective lens, the margin of the tilt of the optical recording medium with respect to the writing/reading characteristic is narrower.

[03]   In an optical information writing/reading device which shortens the wavelength of a light source and increases the numerical aperture of an objective lens to increase the recording density, the thickness of a protective layer of an optical recording medium is smaller to secure the margin of the tilt of the optical recording medium with respect to the write/read characteristic. For example, in a standard CD (compact disc) having a capacity of 650MB, the wavelength of a light source is 780nm, the numerical aperture of an objective lens is 0.45, and the thickness of a protective layer of an optical disc is 1.2mm. In a standard DVD (digital versatile disc) having a capacity of 4.7GB, the wavelength of a light source is 650nm, the numerical aperture of an objective lens is 0.6, and the thickness of a protective layer of an optical disc is 0.6mm.

[04]   In a typical optical head, an objective lens is designed to cancel a spherical aberration to an optical disc having a protective layer having a certain thickness. When writing and reading are performed onto/from optical discs having protective layers having different thicknesses, the spherical aberration remains and correct writing and reading cannot be performed. Accordingly, there is proposed an optical head unit having a compatible function which can perform writing and reading onto/from both of an optical disc of the DVD standard and an optical disc of the CD standard. Such kind of optical head units are classified into one using a single objective lens and one using a plurality of objective lenses. The optical head unit using a plurality of objective lenses has a construction slightly more complicated than that of the optical head unit using a single objective lens. However, the respective objective lenses can be optimally designed for the

2

optical discs of the respective standards, so that the writing/reading performance to the optical

discs of the respective standards is excellent.

[05]   As an example of a prior art optical head unit using a plurality of objective lenses, which

can perform writing and reading onto/from both of an optical disc of the DVD standard and an

optical disc of the CD standard, Japanese Published Application 2000-242943 discloses an

optical head unit shown in FIG. 1.

[06]   As shown in FIG. 1, an optical head unit 101 in the prior art has a first optical system

102a, a second optical system 102b, a first objective lens 103a mounted on a first actuator 104a,

and a second objective lens 103b mounted on a second actuator 104b.

[07]   The first optical system 102a and the second optical system 102b have a semiconductor

laser, not shown, as a light source. A photodetector, not shown, receives a light from an optical

disc 105 of the DVD standard or the CD standard. The wavelength of an emitted light of the

semiconductor laser in the first optical system 102a is 650nm, and the wavelength of an emitted

light of the semiconductor laser in the second optical system 102b is 780nm.

[08]   The emitted light from the semiconductor laser in the first optical system 102a is incident

upon the first objective lens 103a and is focused onto the optical disc 105 of the DVD standard

having a protective layer having a thickness of 0.6mm. A reflected light from the optical disc 105

passes through the first objective lens 103a in the reverse direction to be received by the

photodetector in the first optical system 102a. In addition, the emitted light from the

semiconductor laser in the second optical system 102b is incident upon the second objective lens

103b and is focused onto the optical disc 105 of the CD standard having a protective layer

having a thickness of 1.2mm. A reflected light from the optical disc 105 passes through the

3

second objective lens 103b in the reverse direction to be received by the photodetector in the second optical system 102b.

[09]   The first objective lens 103a has a spherical aberration canceling a spherical aberration caused when the light with a wavelength of 650nm passes through the protective layer having a thickness of 0.6mm of the optical disc 105. The second objective lens 103b has a spherical aberration canceling a spherical aberration caused when the light with a wavelength of 780nm passes through the protective layer having a thickness of 1.2mm of the optical disc 105.

[10]   The optical head unit 101 is moved between the innermost circumference and the outermost circumference of the optical disc 105 in the direction of the arrows of FIG. 1 along two rails 106a and 106b arranged in parallel with each other.

[11]   In FIG. 1, the numeral 131a denotes a first optical path connecting the first optical system 102a and the first objective lens 103a, and the numeral 131b denotes a second optical path connecting the second optical system 102b and the second objective lens 103b.

[12]   In recent years, to increase the recording density, there has been proposed a next-generation standard in which the wavelength of a light source is shorter, the numerical aperture of an objective lens is higher, and the thickness of a protective layer of an optical recording medium (optical disc) is smaller. For example, with the name of Blu-ray Disc (BD), there has been proposed a next-generation standard having a capacity of 23.3GB in which the wavelength of a light source is 405nm, the numerical aperture of an objective lens is 0.85, and the thickness of a protective layer (cover layer) of an optical disc is 0.1mm. Accordingly, what is desired is an optical head unit having a compatible function which can perform writing and reading onto/from any of an optical disc of such next-generation standard and conventional optical discs of the DVD standard and the CD standard. However, there has not yet been an optical head unit using a

4

plurality of objective lenses which can perform writing and reading onto/from any of the optical

disc of the next–generation standard and the conventional optical discs of the DVD standard and

the CD standard.

SUMMARY OF THE INVENTION

[13]　To overcome the problems in the prior art described above, and to overcome other

problems that will become apparent to one of ordinary skill in the art upon reading and

understanding the present specification, the present invention discloses an optical head unit and

optical information writing/reading device.

[14]　The present invention provides an optical head unit having a plurality of objective lenses

and an optical information writing/reading device, which can write and read information

onto/from optical discs of any standard.

[15]　According to a first aspect of the present invention, an optical head unit comprises a first

light source emitting a light with a first wavelength, a second light source emitting a light with a

second wavelength, a third light source emitting a light with a third wavelength, a first objective

lens irradiating the light emitted from the first light source onto an optical recording medium, a

second objective lens irradiating the light emitted from the second light source or the light

emitted from the third light source onto an optical recording medium, and a photodetector

receiving a reflected light from the optical recording medium.

BRIEF DESCRIPTION OF THE DRAWINGS

[16]　FIG. 1 is a plan view showing the schematic construction of a prior art optical head unit.

[17]　FIG. 2 is a plan view showing the schematic construction of an optical head unit of a first

embodiment of the present invention.

[18]　FIG. 3 is a view showing the construction of a first optical system used in the optical

head unit of FIG. 2.

5

[19]   FIG. 4 is a view showing the construction of a second optical system used in the optical

head unit of FIG. 2.

[20]   FIG. 5(a) is a view showing the construction of an objective lens used in the first optical

system of the optical head unit of FIG.2, and FIG. 5(b) is a view showing the construction of an

objective lens used in the second optical system of the optical head unit of FIG.2.

[21]   FIGS. 6(a) and (b) are views showing the constructions of photodetectors used in the

optical head unit of FIG. 2 and light spots.

[22]   FIG. 7 is a diagram showing the relation between the angle deviation between the tracks

of an optical disc and the division lines of the photodetectors and the offsets (calculated values)

of focus error signals (astigmatism signals) with it in the optical head unit of FIG. 2.

[23]   FIG. 8 is a diagram showing the relation between the angle deviation between the tracks

of an optical disc and the division lines of the photodetectors and the modulation factors

(calculated values) of track error signals (push–pull signals) with it in the optical head unit of

FIG. 2.

[24]   FIG. 9 is a view showing the position relation between the centers of the objective lenses

and the center of the optical disc in the optical head unit of FIG. 2.

[25]   FIG. 10 is an explanatory view showing the construction of a diffraction optical device

used in the optical head unit of FIG. 2.

[26]   FIG. 11 is a plan view showing the schematic construction of an optical information

writing/reading device of a second embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[27]   A schematic construction of an optical head unit 1 of a first embodiment of the present

invention is shown in FIG. 2. As shown in FIG. 2, the optical head unit 1 has a first optical

system 2a, a second optical system 2b, a first actuator 4a, a second actuator 4b, a first objective lens 3a mounted on the first actuator 4a, and a second objective lens 3b mounted on the second actuator 4b. The first optical system 2a and the second optical system 2b each have a semiconductor laser as a light source, and a photodetector receiving a reflected light from an optical disc 5 of the next–generation standard, the DVD standard or the CD standard. An illustrative wavelength of an emitted light of the semiconductor laser in the first optical system 2a is 405nm. An illustrative wavelength of an emitted light of the semiconductor laser in the second optical system 2b is 650nm or 780nm. As indicated by the arrows in FIG. 2, the optical head unit 1 is moved between the innermost circumference and the outermost circumference of the optical disc 5 along two rails 6a and 6b arranged in parallel with each other.

[28]   The emitted light (wavelength of 405nm) from the semiconductor laser in the first optical system 2a is incident via a first optical path 31a upon the first objective lens 3a to be focused onto the optical disc 5. A reflected light from the optical disc 5 passes through the first objective lens 3a in the reverse direction to be received by the photodetector in the first optical system 2a.

[29]   The emitted light (wavelength of 650nm) from one of the semiconductor lasers in the second optical system 2b is incident via a second optical path 31b upon the second objective lens 3b to be focused onto the optical disc 5. A reflected light from the optical disc 5 passes through the second objective lens 3b in the reverse direction to be received by the photodetector in the second optical system 2b. The emitted light (wavelength of 780nm) from the other of the semiconductor lasers in the second optical system 2b is incident via the second optical path 31b upon the second objective lens 3b to be focused onto the optical disc 5. A reflected light from the optical disc 5 passes through the second objective lens 3b in the reverse direction to be received by the photodetector in the second optical system 2b.

7

[30]   The first objective lens 3a has a spherical aberration canceling a spherical aberration caused when the light with a wavelength of 405nm passes through a protective layer having a thickness of 0.1mm and is optimized for the optical recording medium of the next-generation standard. To this, the second objective lens 3b has a spherical aberration substantially canceling a spherical aberration caused when the light with a wavelength of 650nm passes through a protective layer having a thickness of 0.6mm and has a spherical aberration substantially canceling a spherical aberration caused when the light with a wavelength of 780nm passes through a protective layer having a thickness of 1.2mm. In other words, the spherical aberration of the second objective lens 3b is set to substantially cancel a spherical aberration caused when the light with a wavelength of 650nm passes through the protective layer having a thickness of 0.6mm and to substantially cancel a spherical aberration caused when the light with a wavelength of 780nm passes through the protective layer having a thickness of 1.2mm. In this way, the second objective lens 3b is not optimized for only the optical disc of the DVD standard or only the optical disc of the CD standard. However, its remaining spherical aberration is within the allowable range for any of the DVD standard and the CD standard. Thus, the second objective lens 3b can correctly write and read information onto/from the optical disc of any of the DVD standard and the CD standard.

[31]   The construction of the first optical system 2a is shown in FIG. 3. The emitted light with a wavelength of 405nm from a semiconductor laser 7a is divided into three lights of a zero order light and ± first order diffraction lights by a diffraction optical device 8a. These three lights are collimated by a collimator lens 9a to be incident as P polarized light upon a polarization beam splitter 10a. Almost of these lights pass through the polarization beam splitter 10a. Thereafter, they pass through a 1/4 wave plate 11a to be converted from a linearly polarized light to a

8

circularly polarized light, and further pass through a relay lens 12a and a relay lens 12b to be irradiated upon the optical disc 5 by the first objective lens 3a.

[32]   The reflected lights (wavelength of 405nm) from the optical disc 5 pass through the first objective lens 3a in the reverse direction, and then pass through the relay lens 12b and the relay lens 12a in the reverse direction. Further, they pass through the 1/4 wave plate 11a to be converted from a circularly polarized light to a linearly polarized light which the polarization direction is orthogonal to that in the going path. They are then incident as S polarized light upon the polarization beam splitter 10a for reflection of almost of them, and pass through a cylindrical lens 13a and a lens 14a to be received by a photodetector 15a.

[33]   The photodetector 15a of the first optical system 2a is arranged in about the middle of two focal lines of the cylindrical lens 13a and the lens 14a.

[34]   Generally, when the thickness of a protective layer of an optical disc is deviated from the design value, a spherical aberration caused by the thickness deviation of the protective layer fluctuates the shape of the focal spot on the optical disc, resulting in deterioration of the writing/reading characteristic. The spherical aberration is inversely proportional to the wavelength of a light source and is proportional to the biquadrate of the numerical aperture (NA) of an objective lens. The shorter the wavelength of the light source and the higher the numerical aperture of the objective lens, the margin of the thickness deviation of the protective layer of the optical disc with respect to the writing/reading characteristic is narrower. For example, when the wavelength of the semiconductor laser 7a as the light source is 405nm and the numerical aperture of the objective lens 3a is 0.85, the margin of the thickness deviation of the protective layer is insufficient. The thickness deviation of the protective layer of the optical disc 5 may be corrected. When any one of the relay lens 12a and the relay lens 12b is moved in its optical axis

9

direction by the actuator, not shown, the magnification of the first objective lens 3a is changed to vary the spherical aberration. The position of the optical axis direction of any one of the relay lenses 12a and 12b is adjusted to cause a spherical aberration canceling a spherical aberration caused by the thickness deviation of the protective layer of the optical disc 5 by the first objective lens 3a. The thickness deviation of the protective layer of the optical disc 5 can be corrected to eliminate adverse affection on the writing/reading characteristic.

[35]   The construction of the second optical system 2b is shown in FIG. 4. The emitted light with a wavelength of 650nm from a semiconductor laser 7b is divided into three lights of a zero order light and ± first order diffraction lights by a diffraction optical device 8b. These three lights are collimated by a collimator lens 9b to be incident as the S polarized light upon a polarization beam splitter 10b. Almost all of these lights are reflected by the polarization beam splitter 10b, and almost all of them pass through a polarization beam splitter 10c. Thereafter, they pass through a 1/4 wave plate 11b to be converted from a linearly polarized light to a circularly polarized light and are irradiated onto the optical disc 5 by the second objective lens 3b.

[36]   The reflected lights (wavelength of 650nm) from the optical disc 5 pass through the second objective lens 3b in the reverse direction, and then pass through the 1/4 wave plate 11b to be converted from a circularly polarized light to a linearly polarized light which the polarization direction is orthogonal to that in the going path. Almost all of the reflected lights pass through the polarization beam splitter 10c to be incident as the P polarized light upon the polarization beam splitter 10b. Almost all of them pass therethrough, thereby passing through a cylindrical lens 13b and a lens 14b to be received by a photodetector 15b.

[37]   In addition, the emitted light with a wavelength of 780nm from a semiconductor laser 7c is divided into three lights of a zero order light and ± first order diffraction lights by a diffraction

10

optical device 8c. These three lights are collimated by a collimator lens 9c to be incident as the S

polarized light upon a polarization beam splitter 10c. Almost all of these lights are reflected by

the polarization beam splitter 10c. They pass through the 1/4 wave plate 11b to be converted

from a linearly polarized light to a circular polarized light and are irradiated onto the optical disc

5 by the second objective lens 3b.

[38]   The reflected lights (wavelength of 780nm) from the optical disc 5 pass through the

second objective lens 3b in the reverse direction, and then pass through the 1/4 wave plate 11b to

be converted from a circular polarized light to a linearly polarized light which the polarization

direction is orthogonal to that in the going path. The reflected lights are incident as the P

polarized light upon the polarization beam splitter 10c so that almost all of them pass

therethrough. Almost all of them pass through the polarization beam splitter 10b, thereby passing

through the cylindrical lens 13b and the lens 14b to be received by the photodetector 15b.

[39]   The photodetector 15b of the second optical system 2b is arranged in about the middle of

two focal lines of the cylindrical lens 13b and the lens 14b.

[40]   FIGS. 5(a) and 5(b) show illustrative examples of the first objective lens 3a and the

second objective lens 3b, respectively. The first objective lens 3a has a numerical aperture of

0.85. As shown in FIG. 5(a), the first objective lens 3a has two lenses in two groups of a first

lens 16a and a second lens 16b. As a specific example of such objective lens having two lenses

in two groups, for example, there is one described in Japanese Journal of Applied Physics, Vol.

36, pp. 456–459.

[41]   The first objective lens 3a can also be constructed by a single lens. As a specific example

of an objective lens having a single lens, there is one described in International Symposium on

Optical Memory–2001, Technical Digest, pp. 26–27.

[42]   The light with a wavelength of 405nm incident upon the first objective lens 3a is focused onto the optical disc 5a of the next–generation standard having the protective layer having an illustrative thickness of 0.1mm to form an optimum light spot.

[43]   In the second objective lens 3b, the numerical aperture to the light with the wavelength of 650nm is 0.6, and the numerical aperture to the light with a wavelength of 780nm is 0.45. It may be constructed by a diffraction–refraction combined lens formed with a diffraction grating on a first surface. As a specific example of such objective lens having a diffraction–refraction combined lens, there is one described in Optical Design and Fabrication 2000, Proceedings, pp. 93–96.

[44]   The light with a wavelength of 650nm incident upon the second objective lens 3b is focused onto the optical disc 5b of the DVD standard having the protective layer having a thickness of 0.6mm to form a light spot. The light with a wavelength of 780nm incident upon the second objective lens 3b is focused onto the optical disc 5c of the CD standard having the protective layer having a thickness of 1.2mm to form a preferable light spot.

[45]   The first objective lens 3a is optimally designed to the optical disc of the next–generation standard and can obtain writing/reading performance sufficient for the optical disc of the next–generation standard having a narrow writing/reading margin. On the other hand, the second objective lens 3b is not optimally designed for only the optical disc of the DVD standard or the optical disc of the CD standard but is designed for both. The optical disc of the DVD standard and the optical disc of the CD standard have a relatively wide writing/reading margin.

[46]   The construction of the photodetector 15a of the first optical system 2a is shown in FIG. 6(a). The photodetector 15a has, for the zero order light, light reception parts 18a, 18b, 18c and 18d divided into four by a division line in parallel with the radius direction of the optical disc 5

and a division line in parallel with the tangent direction of the optical disc 5, and for the + 1 order diffraction light, light reception parts 18e and 18f divided into two by a division line in parallel with the radius direction of the optical disc 5, and for the − 1 order diffraction light, light reception parts 18g and 18h divided into two by a division line in parallel with the radius direction of the optical disc 5. The radius direction is a direction along which the optical head unit moves from an innermost portion of the optical disc to an outermost portion of the optical disc. The tangent direction is perpendicular to the radius direction. In addition, the light reception parts are in order of the tangent direction. In Fig.2, the parallel direction with the rail is the radius direction.

[47] The zero order light of three reflected lights from the optical disc 5 forms a light spot 17a on the four light reception parts 18a, 18b, 18c and 18d. The + 1 order diffraction light of the reflected lights forms a light spot 17b on the two light reception parts 18e and 18f. The − 1 order diffraction light of the reflected lights forms a light spot 17c on the two light reception parts 18g and 18h.

[48] Electric signal outputs obtained from the eight light reception parts 18a to 18h of the photodetector 15a are expressed as V18a to V18h, respectively. A focus error signal is obtained from operation of (V18a + V18d) − (V18b + V18c) by a known "astigmatism method". A track error signal is obtained from operation of (V18a + V18b) − (V18c + V18d) − K [(V18e + V18g) − (V18f + V18h) (K is a constant.) by a known "difference push–pull method". An RF signal (data signal) from the optical disc 5 is obtained from operation of (V18a + V18b + V18c + V18d).

[49] The construction of the photodetector 15b of the second optical system 2b is the same as shown in FIG. 6(a).

13

[50] In addition, in this embodiment, when the optical head unit 1 is moved between the innermost circumference and the outermost circumference of the optical disc 5, distance La between a straight line including a track of the center of the first objective lens 3a and the center O of the optical disc 5 may be shorter than distance Lb between the straight line including the track of the center of the second objective lens 3b and the center O of the optical disc 5 as shown in FIG.2. In other words, La < Lb may be set.

[51] When the optical head unit 1 is moved between the innermost circumference and the outermost circumference of the optical disc 5 and the straight line including the track of the center of the objective lens 3a or 3b does not pass through center O of the optical disc 5, the angle between the tracks of the optical disc 5 and the division lines of the photodetectors 15a, 15b (division lines in parallel with the tangent direction of the optical disc 5) is changed according to the radius of the optical disc 5 where the center of the objective lens 3a or 3b is positioned. When the angle is deviated from 0°, offset occurs in the focus error signal of the "astigmatism method" and the modulation factor of the track error signal of the "push–pull method" is lowered.

[52] FIG. 7 shows results calculated by standardizing, by sum signals, the offsets of the focus error signals of the "astigmatism method" with angle deviation between the tracks of the optical disc 5 and the division lines of the photodetectors 15a, 15b (division lines in parallel with the tangent direction of the optical disc 5) in the optical discs 5 of the next–generation standard using a blue light, the DVD standard, and the CD standard. In addition, FIG. 8 shows results calculated by standardizing, by sum signals, the modulation factors of the track error signals of the "push– pull method" with the angle deviation in the optical discs 5 of these three standards.

[53]   In FIG.7 and FIG.8, a curved line of the next–generation standard(blue) mostly

corresponds with a curved line of the DVD standard.

[54]   As shown in FIG. 8, the modulation factor of the track error signal is not lowered to

about 20° of angle deviation. As shown in FIG. 7, the offsets of the focus error signals are

increased in proportion to increase of angle deviation. Comparing a slope of the curved line of

the next-generation standard, the DVD standard, with the CD standard in a scope of 0° to 25° of

angle deviation, the offsets of the focus error signals in the next–generation standard (blue) and

the DVD standard are about 3/4 of the offset of the focus error signal in the CD standard.

However, the allowable value of the offset of the focus error signal is generally proportional to

the wavelength of the light source and is inversely proportional to the square of the numerical

aperture of the objective lens. The allowable values of the offsets of the focus error signals in the

next–generation standard and the DVD standard are, for example, about 15% and about 47% of

the allowable value of the offset of the focus error signal in the CD standard, respectively.

Accordingly, the percentage of the offset of the focus error signal caused with the angle

deviation to its allowable value is the largest in the next–generation standard. Therefore, the less

angle deviation amount in the next–generation standard, the more effective to avoid a decrease in

the focus error signal as compared to the angle deviation amount in the DVD standard or the CD

standard.

[55]   According to setting the position of the objective lens, the angle deviation amount

between the tracks of the optical disc 5 of the next–generation standard and the division line of

the photodetector is smaller than that between the tracks of the optical discs 5 of the DVD

standard and the CD standard and the division line of the photodetector.

[56]   FIG. 9 shows the position relation between the centers of the objective lenses and the center O of the optical disc 5.

[57]   As shown in FIG. 9, the distance between straight line L including the tracks of the centers of the objective lenses when the optical head unit 1 is moved between the innermost circumference and the outermost circumference of the optical disc 5 and the center of the optical disc 5 is D, and the radiuses of the innermost circumference and the outermost circumference of the optical disc 5 are R_{min} and R_{max}, respectively. The angle deviation amounts between the tracks of the innermost circumference and the outermost circumference of the optical disc 5 and the division line of the photodetector 15a (see FIG. 6) are θ_{min} and θ_{max}, respectively, by the following equations.

$$\sin \theta_{min} = D/R_{min}, \ \sin \theta_{max} = D/R_{max}$$

[58]   The division line of the photodetector 15a may be tilted with respect to the direction orthogonal to the tracks of the centers of the objective lenses (that is, the straight line L) by (θ_{min} + θ_{max})/2 as a photodetector 15c shown in FIG.6(b). Accordingly, both of the angle deviation amounts between the tracks of the innermost circumference and the outermost circumference of the optical disc 5 and the division line of the photodetector 15c can be reduced to (θ_{max} − θ_{min})/2.

[59]   The light spots 17d, 17e and 17f of FIG. 6(b) correspond to the light spots 17a, 17b and 17c of FIG. 6(a), respectively. The light reception parts 18i to 18p of FIG. 6(b) correspond to the light reception parts 18a to 18h of FIG. 6(a), respectively. The construction shown in FIG. 6(b) is the same as the construction shown in FIG. 6(a) except that the two division lines in parallel with the radius direction and the tangent direction of the optical disc 5 are tilted with respect to the direction orthogonal to the tracks of the centers of the objective lenses (that is, the straight line L) by (θ_{min} + θ_{max})/2.

16

[60]   In the same manner, the photodetector 15b may be replaced by the construction shown in FIG. 6(b).

[61]   In a case that the straight line L including the tracks of the centers of the objective lenses 3a, 3b when the optical head unit 1 is moved between the innermost circumference and the outermost circumference of the optical disc 5 does not pass through the center of the optical disc 5, the angle between the track of the optical disc 5 and the focal spot row on the optical disc 5 is changed according to the radius of the optical disc 5 where the centers of the objective lens 3a, 3b are positioned. Therefore, the phase between the push–pull signal of the new order light and that of the ± 1 order diffraction lights may be compensated according to the angle between the track of the optical disc 5 and the focal point row on the optical disc 5 to avoid a change of an amplitude of the track error signal by the "difference push-pull method". Instead, a diffraction optical device formed with the grating pattern shown in FIG. 10 may be used as the diffraction optical device 8a.

[62]   The diffraction grating pattern of FIG. 10 is divided into four areas 19a, 19b, 19c and 19d by a straight line in parallel with the radius direction of the optical disc 5 and a straight line in parallel with the tangent direction of the optical disc 5 passing through the optical axis of an incident light. The phases of the gratings in the areas 19a, 19d and the phases of the gratings in the areas 19b, 19c are shifted from each other by $\pi/2$. In other words, the phase of the grating in the area 19a is shifted from the phase of the grating in the area 19b by $\pi/2$ and is also shifted from the phase of the grating in the area 19c by $\pi/2$. The phase of the grating in the area 19d is shifted from the phase of the grating in the area 19b by $\pi/2$ and is also shifted from the phase of the grating in the area 19c by $\pi/2$.

[63]   According to the diffraction grating pattern as shown in FIG. 10, the amplitude of the push–pull signals of the ± first order diffraction lights from the diffraction optical device 8a as the sub beam is always 0. Therefore, the amplitude of the track error signal of the "difference push–pull method" is not changed as described in Japanese Journal of Applied Physics, Vol. 38, pp. 1761–1767.

[64]   Similar to this, as the diffraction optical devices 8b, 8c of the second optical system 2b, the diffraction optical device formed with the grating pattern shown in FIG. 10 may be used.

[65]   As described above, the optical head unit 1 of the first embodiment of the present invention is provided with the first objective lens 3a, the first optical system 2a, the second objective lens 3b, and the second optical system 2b. When the protective layer of the optical disc 5 has a first thickness corresponding to the next–generation standard, the semiconductor laser (first light source) 7a of the first optical system 2a and the first objective lens 3a are used. When the protective layer of the optical disc 5 has a second thickness corresponding to the DVD standard, the semiconductor laser (second light source) 7b of the second optical system 2b and the second objective lens 3b are used. When the protective layer of the optical disc 5 has a third thickness corresponding to the CD standard, the semiconductor laser (third light source) 7c of the second optical system 2b and the second objective lens 3b are used. Further, the wavelength of the emitted light of the semiconductor laser 7a corresponds to the next–generation standard. The wavelength of the emitted light of the semiconductor laser 7b may correspond to the DVD standard, the wavelength of the emitted light of the semiconductor laser 7c may correspond to the CD standard. Therefore, information can be written or read onto/from any of the optical discs. Information can be written or read, not only onto/from conventional optical recording

media of the DVD standard and the CD standard, but also onto/from an optical recording

medium of the next–generation standard using a blue light.

[66]   FIG. 11 shows the schematic construction of an optical information writing/reading

device of a second embodiment of the present invention.

[67]   The optical information writing/reading device is constructed by adding a first

writing/reading circuit 22a, a second writing/reading circuit 22b, a third writing/reading circuit

22c, a switching circuit 21, and a control circuit 20, to the optical head unit 1 of the above–

described first embodiment.

[68]   The first writing/reading circuit 22a generates an input signal to the semiconductor laser

7a provided in the first optical system 2a based on a write signal to the optical disc 5 of the next–

generation standard. It generates a read signal from the optical disc 5 based on an output signal

from the photodetector 15a provided in the first optical system 2a.

[69]   The second writing/reading circuit 22b generates an input signal to the semiconductor

laser 7b provided in the second optical system 2b based on a write signal to the optical disc 5 of

the DVD standard. It generates a read signal from the optical disc 5 based on an output signal

from the photodetector 15b provided in the second optical system 2b.

[70]   The third writing/reading circuit 22c generates an input signal to the semiconductor laser

7c provided in the second optical system 2b based on a write signal to the optical disc 5 of the

CD standard. It generates a read signal from the optical disc 5 based on an output signal from the

photodetector 15b provided in the second optical system 2b.

[71]   The switching circuit 21 switches a transmission path of the input signal from the first

writing/reading circuit 22a to the semiconductor laser 7a of the first optical system 2a, a

transmission path of the input signal from the second writing/reading circuit 22b to the

19

semiconductor laser 7b of the second optical system 2b, and a transmission path of the input

signal from the third writing/reading circuit 22c to the semiconductor laser 7c of the second

optical system 2b. In addition, it switches a transmission path of the output signal from the

photodetector 15a of the first optical system 2a to the first writing/reading circuit 22a, a

transmission path of the output signal from the photodetector 15b of the second optical system

2b to the second writing/reading circuit 22b, and a transmission path of the output signal from

the photodetector 15b of the second optical system 2b to the third writing/reading circuit 22c.

[72]   The control circuit 20 controls the operation of the switching circuit 21 as follows. When

the optical disc 5 of the next–generation standard is inserted into the optical information

writing/reading device, it is detected to transmit an input signal from the first writing/reading

circuit 22a to the semiconductor laser 7a and an output signal from the photodetector 15a to the

first writing/reading circuit 22a. When the optical disc 5 of the DVD standard is inserted

thereinto, an input signal is transmitted from the second writing/reading circuit 22b to the

semiconductor laser 7b and an output signal is transmitted from the photodetector 15b to the

second writing/reading circuit 22b. When the optical disc 5 of the CD standard is inserted

thereinto, an input signal is transmitted from the third writing/reading circuit 22c to the

semiconductor laser 7c and an output signal is transmitted from the photodetector 15b to the

third writing/reading circuit 22c.

[73]   As described above, the optical information writing/reading device of the second

embodiment of the present invention includes the above–described optical head unit 1 of the first

embodiment of the present invention and switches and uses the optical systems and the

writing/reading circuits depended upon the kind of the optical disc 5 inserted. Therefore,

20

information can be written or read onto/from the optical disc 5 corresponding to any kinds of optical discs.

[74]   The previous description of embodiments is provided to enable a person skilled in the art to make and use the present invention. Moreover, various modifications to these embodiments will be readily apparent to those skilled in the art, and the generic principles and specific examples defined herein may be applied to other embodiments without the use of inventive faculty. Therefore, the present invention is not intended to be limited to the embodiments described herein but is to be accorded the widest scope as defined by the limitations of the claims and equivalents.